

Energy density and Gravitational Pressure of the PPC Gravity

Important Points about Energy density and Gravitational Pressure of Pansos Upadhyay's Pressure–Curvature Law-of Gravity (PPC Law of Gravity)

Definitions, Regimes, and Consistency Conditions

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Abstract

Pansos Upadhyay's Pressure–Curvature (PPC) Law of Gravity proposes an interpretation of gravitation in which gravitational pressure, energy density, pressure gradients, and spacetime curvature play central roles. The existing PPC framework includes the relations $E_d = \rho c^2$ and $P_g = \omega E_d$. Where P_g is Gravitational Pressure, E_d is Energy Density and ω is dimensionless equation of state parameter or dimensionless pressure scaling parameter.

1. Fundamental Definitions

1.1 Energy Density

In relativistic physics, mass density ρ corresponds to energy density:

$$E_d = \rho c^2$$

This is a definition, not an assumption.

1.2 Gravitational Pressure

In PPC gravity, gravitational interaction is interpreted through a **gravitational pressure field** P_g , defined generally as:

$$P_g = \omega E_d = \omega \rho c^2$$

where

- ω is a dimensionless pressure-scaling parameter,
- $0 \leq \omega \leq 1$.

2. Meaning of the Parameter ω

The parameter ω characterizes the physical regime of matter/energy.

Regime	Physical system
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Non-relativistic	planets, moons, stars
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Relativistic	radiation-dominated
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Extreme / stiff	near black holes
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Physical system	Value of ω
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planets, moons, stars	$\omega < 1$
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radiation-dominated	$\omega = \frac{1}{3}$
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near black holes	$\omega = 1$
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Thus, ω controls how much of energy density manifests as gravitational pressure.

2. Definition of Surface Force

The surface force in PPC-gravity is defined as:

$$F_s = P_g A$$

where

- P_g is the local gravitational pressure, and
- A is the effective surface area of the body.

This force exists **only for extended bodies** and represents the direct action of gravitational pressure on matter.

3. Origin of Surface Force

Surface force is a **derived effect**, not a fundamental cause. Its origin follows the logical sequence:

Mass density $\rightarrow$ Pressure $\rightarrow$ Gravitational field $\rightarrow$ Interaction (on extended bodies)

Thus:

- Pressure is generated by mass density.
- Field force establishes the pressure field, and
- Surface force appears when that pressure acts on a finite surface.

Point-like test particles experience only the field force; surface force emerges only when matter has spatial extent.

3. Maximum-Pressure Limit

The relation

$$P_g = E_d = \rho c^2$$

is valid if and only if:

$$\omega = 1$$

This corresponds to the maximum gravitational pressure state, applicable to:

- black holes,
- near-event-horizon regions,
- extreme relativistic collapses.

4. Ordinary Astrophysical Systems

For systems such as:

- Moon–Earth,
- Earth–Sun,
- planetary and stellar dynamics,

matter is **non-relativistic**, therefore:

$$\omega < 1 \quad \Rightarrow \quad P_g < \rho c^2$$

In these systems:

- gravitational pressure exists,
- but it is far below the maximum-pressure limit,
- orbital motion arises from pressure gradients, not from extreme pressure.

4. Distinction Between Field Force and Surface Force

- The field force $F_{g,ext} = -\nabla P_g$ governs acceleration, free fall, and orbital motion.
- The surface force $F_s = P_g A$ governs the physical response of matter.

This distinction provides conceptual clarity:

- Motion through space is governed by the field force.
- Physical interaction with gravity is governed by surface force.

5. Pressure-Gradient Force (Field Force)

The physical force associated with gravitational pressure is given by:

$$\mathbf{F} = -\nabla P_g$$

Substituting the general PPC definitions:

$$\mathbf{F} = -\nabla (\omega \rho c^2)$$

This expression:

- reproduces standard gravitational acceleration in weak fields,
- introduces a new force law,
- provides a novel physical interpretation of gravity.

5. Physical Roles of Surface Force

5.1 Binding of Extended Bodies

Surface force contributes to the structural cohesion of planets, stars, and moons. It explains why extended bodies remain intact within strong gravitational environments and resist disruption.

5.2 Tidal Effects and Deformation

When gravitational pressure varies across a body's surface, **differential surface forces** arise. These produce:

- tides,
- stretching and compression,
- internal stress and heating.

This mechanism naturally explains tidal phenomena in systems such as Earth–Moon and star–planet interactions.

6. Relation to General Relativity

General Relativity already incorporates pressure through the stress–energy tensor:

$$T_{\mu\nu} = \left(\rho + \frac{P}{c^2}\right) u_\mu u_\nu + P g_{\mu\nu}$$

In the weak-field limit:

$$\nabla^2 \phi = 4\pi G \left(\rho + \frac{3P}{c^2} \right) \approx 4\pi G \rho (1 + 3\omega)$$

Thus:

- pressure is a genuine source of curvature,
- PPC gravity **does not modify** GR equations,
- it clarifies the physical meaning of pressure in curvature generation.

PPC SYSTEMS SUMMARY TABLE			
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$T_{\mu\nu}^{PPC} = (\rho c^2 + P_g) u_\mu u_\nu + P_g g_{\mu\nu} \quad (9)$			
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Notes: u_μ = 4-velocity vector field $g_{\mu\nu}$ = 4D spacetime metric tensor (signature $(-+++)$) ρ = mass-energy density ($\rho c^2 = E_d$) $u_\mu u_\nu$ = velocity tensor			
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PPC SYSTEM FIELD EQUATION			
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$\mathcal{E}_{\mu\nu} = \frac{8\pi G}{c^2} T_{\mu\nu}^{PPC} \quad (10)$			
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Notes: $\mathcal{E}_{\mu\nu}$ = Einstein tensor (generalized) $T_{\mu\nu}^{PPC}$ = PPC stress-energy tensor G = Newton's gravitational constant c = speed of light in vacuum			
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$$G_{\mu\nu} = \frac{8\pi G}{c^2} T_{\mu\nu}$$

Substituting PPC tensor:

$$G_{\mu\nu} = \frac{8\pi G}{c^2} [(\rho c^2 + P_g) u_\mu u_\nu + P_g g_{\mu\nu}]$$

$$T_{\mu\nu}^{PPC} = (\rho c^2 + P_g) u_\mu u_\nu + P_g g_{\mu\nu} \quad (11)$$

$$T_{\mu\nu}^{PPC} = \rho c^2 \left[(1 + \omega) u_\mu u_\nu + g_{\mu\nu} \right] \quad (12)$$

$$\frac{d^2 x^\mu}{d\tau^2} + \Gamma_{\alpha\beta}^\mu (u_\alpha (E_d + P_g) u_\beta) \frac{dx^\mu}{d\tau} - \frac{dx^\mu}{d\tau} = 0.$$

7. Summary of PPC Relations

$E_d = \rho c^2$

$P_g = \omega E_d = \omega \rho c^2$

$\mathbf{F} = -\nabla P_g$

$\omega < 1 \Rightarrow$ planets, moons, stars
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$\omega = 1 \Rightarrow$ radiation-pressure (black holes)

Case	E_d	P_g	∇P_g
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1. Strict vacuum	0	0	0
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2. The source	< 1	< 1	tiny
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3. Near vacuum	$\rightarrow 0$	$\rightarrow 0$	$\rightarrow 0$
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In the local rest frame,

$$T_{\mu\nu}^{PPC} = \begin{pmatrix} E_d & 0 & 0 & 0 \\ 0 & P_g & 0 & 0 \\ 0 & 0 & P_g & 0 \\ 0 & 0 & 0 & P_g \end{pmatrix}$$

u_μ is the corresponding coordinate-dependent form of c .

8. Scientific Scope

- PPC-gravity is an **interpretive framework**, not a new gravitational theory.
- It preserves all predictions of Newtonian gravity and General Relativity.
- It introduces pressure as the causal agent behind curvature.
- Experimental and observational tests remain those of standard gravity.